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REVIEW OF INFORMATION ON HAZARDS TO PERSONNEL FROM HIGH-FREQUENCY ELECTROMAGNETIC RADIATION

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Summary

Foreign and domestic literature on biological effects of electromagnetic radiation has been examined for information relating to safety criteria. Emphasis was placed on obtaining relevant information on frequencies below 300 mc, most particularly on the high-frequency (3 - 30 mc) region. This information is reviewed and evaluated.

Discussion

The question has been raised as to the possible biological effects of electromagnetic radiation of frequencies less than 300 mc (wavelengths less than 1 meter). A review of the open literature relevant to this question was made, the results of which are presented in this report.

Information on biological effects of electromagnetic radiation in the frequency range from about 1 mc (300 meters) to 300,000 mc (1 mm) were reviewed. This revealed a number of reports in the Soviet bloc and to some extent in the western literature dealing with clinical evaluations of people who were exposed to these electromagnetic radiations in their working environment, and a limited number of controlled experiments with intact animals and other

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biological material. Most of this literature deals with electromagnetic radiation in the frequency range 1,000 mc to 10,000 mc. Little attention has been paid to the high-frequency range of 3 mc to 30 mc.

It was necessary to establish criteria for the safety of those exposed to these environments. Owing to the lack of good reliable experimental data different groups of people arrived at very different conclustions. Most of the evidence upon which these safety criteria are based occurred as a result of experience in the 300 - 300,000 mc frequency range. The few safety criteria which exist for frequencies below 300 mc were based upon either extrapolation of higher frequency data or upon very limited experimental evidence.

It is universally agreed that these electromagnetic radiations bring about an increased thermal load on the body. The effect is related primarily to the average field strength and secondarily to the wavelength, i.e., the longer wave lengths penetrate and the shorter wave lengths result in a surface heating. The effect of this theoretical difference may, however, be modified by the heterogenous nature of the body composition.

In contrast to the easily observable thermal effects as yet there is no universal agreement as to an "athermal" or "specific" effect. These have been described as disturbances of the central nervous system and of the vegetative nervous system resulting in various cardiovascular changes and other disruptions. In addition, behavioral changes occur and such effects as general asthenia, tiredness, headache, irritability, loss of memory, loss of appetite, etc. have been reported.

Historically, safety standards have been set and subsequently modified based upon experience. It is universally agreed that when the average power density of the field is greater than 10 mw/cm^2

thermal effects predominate. These could be quantitated and hence served as the basis for the early safety standards. Mumford (1961) gives a well documented account of the historical development of safety criteria and levels in the U.S.

In 1953, Bell Laboratories proposed 0.1 mw/cm^2 as a safe level. Subsequently, it was decided that this level was too conservative. In 1957, Rome Air Development Center Regulation established a "hazardous microwave radiation level of 10 mw/cm^2 or greater over the entire microwave spectrum." This level was also adopted by Bell Telephone Laboratories and the American Telephone and Telegraph Company in the same year. Roman (1958) reported that the Navy Bureau of Medicine had tentatively established 10 mw/cm^2 as a tolerable dose for constant exposure. In 1958, the U.S. Army adopted this level as a tentative safety criteria (see also U.S. Army Regulation No. 40-583). 10 mw/cm^2 was referred to as a safe level and was tentatively adopted by the Armed Forces for all frequencies. U.S. Air Force Manual 161-7, Army Tech. Bulletin 270 (1965) reiterates this value. Various other investigators had proposed different values based on time of exposure and portion of the body exposed.

The most recent effort in this country at establishing criteria for safe levels of exposure was by the U.S. Commission on Standard Safety Levels of Electromagnetic Radiation With Respect to Personnel. The results of their deliberations have been sponsored by the IEEE and the U.S. Department of the Navy and approved and published by the USA Standards Institute on November 1966. They recommend as a radiation protection guide for normal environmental conditions and for incident electromagnetic energy of frequencies from 10 mc to 100,000 mc, an exposure density of 10 mw/cm^2 as averaged over any possible 0.1 hr. Thus, under this criterion, a permissive dosage of 10 mw/cm^2 for periods of 0.1 hours or more is allowed. The allowable energy density is 1 mw-hr/cm^2 during any 0.1 hour period making exposures of more than 10 mw/cm^2 permissible for very short periods of time - i.e., less than 0.1 hours.

These same values were reported in 1965 by Osipov, whose book contains a more extensive discussion of this whole subject area.

Gordon (1964) considered problems of industrial hygiene and of biological effects as produced by various electromagnetic bands. Working with rats, she examined thermally caused death and also threshold intensities of the thermal effect for the various frequency bands. Like many other foreign investigators, however, her concern is primarily with non-thermal effects. She studied the effect of non-thermal intensity radiation as related to wave bands and found central nervous system response manifested by functional changes, occurring at intensities well below thermal threshold intensities. She reports that although her studies on effects of prolonged exposures to very low intensity radiation had just begun, they "could already say that radiation over an interval of one-two months at an intensity not productive of the integral thermal effect, can produce severe functional changes in the central nervous system. The functional changes consisted of alteration in the reactivity of the central nervous system to certain stimuli (rhythmic light) and the appearance in some of the experimental animals of epileptoid predisposition to sensory provocation -- photostimulation in a number of cases producing an epileptiform bioelectric activity."

Minecki (1964) compares the maximum permissible field intensities of various countries and organizations. He states the previously quoted U.S.S.R. values which he dates as 1958 for frequencies greater than 300 mc and a U.S. Armed Forces (1958) value as 10 mw/cm^2 for all frequencies. He also includes a North Atlantic Treaty Organization (1956) value of 0.5 mw/cm^2, and a value of 0.01 mw/cm^2 for frequencies greater than 300 mc which he attributes to the General Post Office of Great Britain (I.S.S.A. Intern. Coll., Warsaw 1963). The Polish (1961) values for frequencies greater than 300 mc are the same as those of the U.S.S.R.

While such is not the case in the U.S., in some other countries, separate criteria do exist for the lower frequencies (below 300 mc) as distinct from the microwave frequencies (300 - 300,000 mc). Among the maximum permissible intensities referred to by Minecki (1964) are U.S.S.R. (1958) values of 5 - 10 v/m (0.003-0.013 mw/cm^2) for frequencies less than 3 mc, Sweden (I.S.S.A. International Colloques, Warsaw, 1963) value of 222 v/m (6.5 mw/cm^2) for frequencies less than 87 mc, and from Czechoslovakia (Marha, K., 1963) values of 5-10 v/m (0.003-0.013 mw/cm^2) for frequencies from 0.01-300 mc.

Opsipov (1965) refers to maximum permissible values for medium and long waves (approximately 100-1500 KC and 10-100 KC, respectively) as 5 v/m (0.003 mw/cm^2) at those points in the work area where there may be workers, and 10 v/m (0.013 mw/cm^2) at work places near operating elements of high frequency installations. He references these values as having been published in "Temporary Sanitary Regulations in Governing Work with Electronic High-Frequency Heaters," approved by the Main State Sanitary Inspector U.S.S.R., 15 January 1955, No. 180-55. He further notes that there is some reason for raising the electric field standard to 20 v/m (0.053 mw/cm^2) and also to specify a maximum permissible intensity for the associated magnetic field.

Osipov (1965) also studied a group of people who were exposed to these lower frequencies and noted certain neurological and cardiovascular symptoms, slight changes in the blood, and functional disorders of the central nervous system. Khazan (1958) studied people exposed to frequencies of 0.3, 0.5, 20 and 75 mc. He found similar changes. With respect to the nervous system, he reports a disruption of the balance between the "processes of excitation and inhibition."

Smurova et al. (1966) also examined people exposed to low frequency radiation. This paper states as permissible industrial exposure limits: 20 v/m (0.053 mw/cm^2) for 3-30 mc radiation and 5 v/m (0.003 mw/cm^2) for 30-300 mc radiation. These safety criteria were recommended in 1964 by the Institute of Industrial Hygiene and Occupational Diseases of the U.S.S.R. Academy of Medical Sciences (Fukalova, 1966).

For the most part, no distinction is made in these safety criteria for continuous as opposed to pulsed waves. As previously mentioned, this is so in the U.S. because of the focus on thermal damage. However, it appears that some consideration should be given to such a distinction. There are reports on experiments in which these two types of radiation were studied which indicate differences in their effects. These reports deal with frequencies both in and below the microwave range.

It is interesting to note that Minecki (1964) gives a Czechoslovakia (Marha, 1963) maximum permissible intensity for frequencies greater than 300 mc which <u>does</u> make a distinction between continuous and pulsed waves. For continuous waves, the allowable intensity is 0.025 mw/cm^2 and for pulsed waves it is 0.01 mw/cm^2. Thus, greater precaution is suggested for exposures to pulsed waves.

Osipov (1965) reviews some of the work which compared effects of pulsed and continuous fields. Some of this work, using 50 mc waves, indicated an opposite direction of effects with continuous and pulsed radiation such that excitation processes prevailed under the action of continuous radiation while inhibition processes predominated as a result of pulsed radiation. Osipov also refers to other authors who found pulsed waves to have a somewhat stronger biological activity than continuous waves and to produce somewhat more pronounced morphological changes.

In a 1964 paper, Presman discusses the question of the non-thermal interaction of electromagnetic fields with the living organism. In this light, he refers to the work of various investigators and, with reference to several of these, mentions that the changes reported were observed over a wide range of frequencies and that they were more pronounced with the use of pulsed radiation.

In a two-part paper published in 1962, Presman and Levitina report on their experiments with the action of continuous and pulsed microwaves on cardiac rhythm. They exposed rabbits to continuous 12.5 cm (2,400 mc) waves for 20 minutes, twelve to thirteen times. The radiation intensity was 7-12 mw/cm^2. The pulsed radiation had a wavelength of 10 cm (3,000 mc), an impulse duration of 1 microsecond, and a frequency of 700 impulses/sec. The average intensity of these pulsed waves was 3-5 mw/cm^2 and it was noted that the impulse intensity exceeded the mean intensity by 1400 times. The irradiations were both dorsal and ventral and non-irradiated parts of the body were shielded with plates absorbing the microwaves. Electrocardiagram recordings were made. A chronotropic effect was found with a shift toward retardation of rate as a result of ventral irradiations and acceleration of rate with dorsal irradiation. The authors report that the chronotropic effect of pulsed irradiation was more pronounced than that caused by continuous waves. In addition to papers cited here, there are other reports in which consideration is given to this question of effects of continuous and pulsed forms of radiation.

Concluding Remarks

There is considerably more data on biological effects and safety guides for electromagnetic radiation in the microwave frequency range, (300 to 30,000 mc) but there is also certain limited data pertaining to lower frequencies (<300 mc).

There is considerable evidence that exposures to microwave radiation (300-30,000 mc) with an average power density greater than 10 mw/cm^2 for periods greater than 0.1 hour can be biologically harmful, largely as a result of thermal effects. Furthermore, for both microwave and lower frequencies, limited clinical studies of humans and controlled animal experiments present evidence of harmful effects at intensities considerably lower than 10 mw/cm^2.

In addition, there are indications that pulsed wave radiation may produce a more pronounced biological effect than continuous wave radiation.

In view of this evidence, it is recommended that, to the extent practical, a conservative approach to safety criteria (approaching the U.S.S.R. standards) be applied, particularly where hazards to non-controlled personnel may be involved.

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